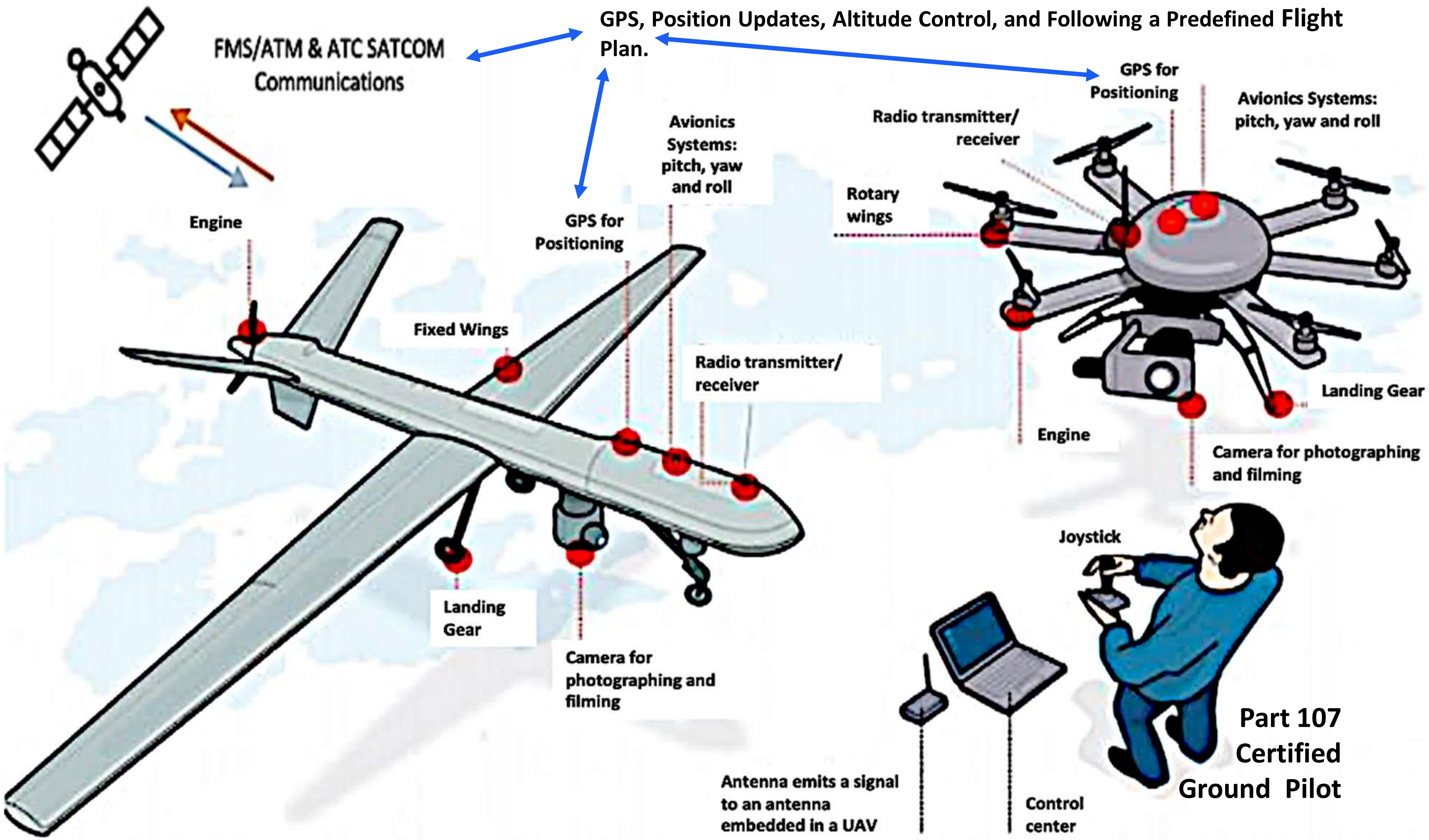
Drones, Vertical Lift Technology, VLT

Wings of change: UAVs and sustainable transportation

- Aeropolis/AIDAA/Euroavia
- Aeronautical Technologies Seminars
- University of Naples
- 26 Jan 2024

Fixed wing and Vertical Lift Technology, VLT, alternatives for Unmanned Aerial Vehicles (UAV) Drones,

Similar systems functions but different Concepts of Operations (CONOPS)

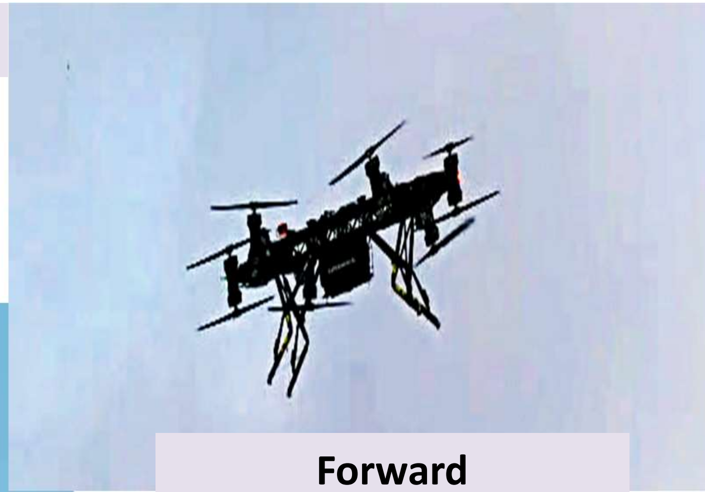


VLT options for Runway Free Operations

Boeing Cargo Air Vehicle, CAV

Autonomous Technology Demonstrator

Cruse



Forward
Maneuver
Loiter

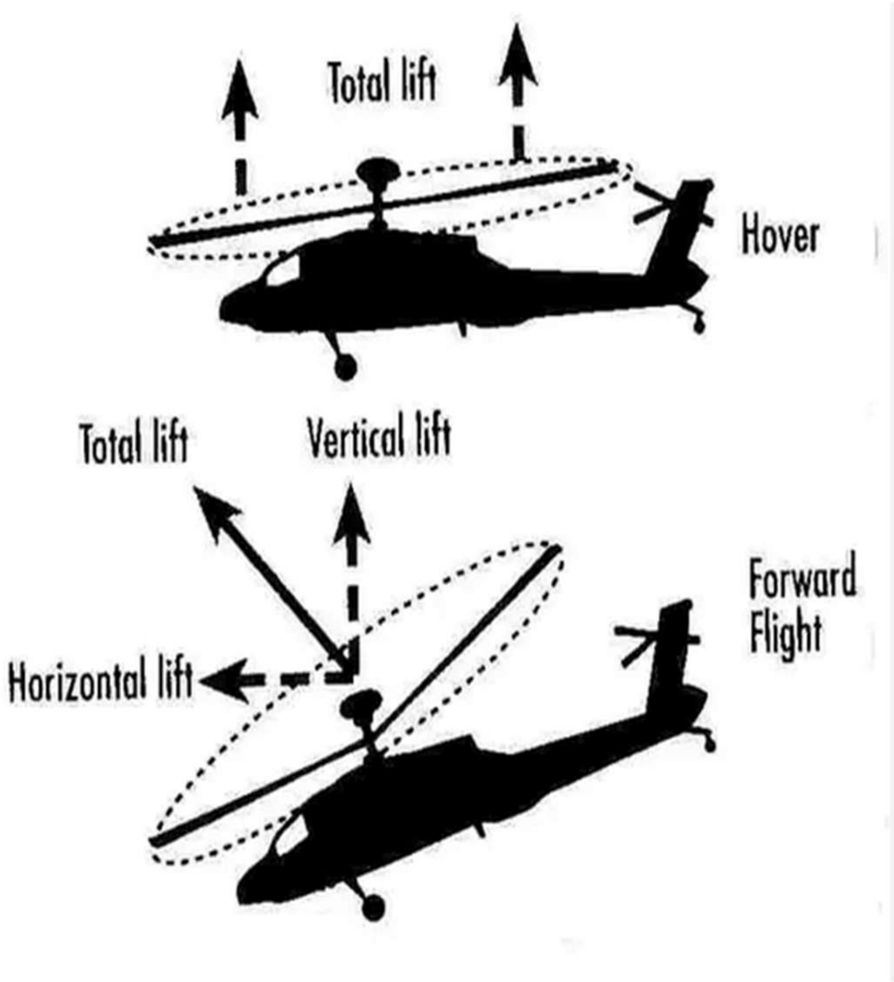
Lift & Hover

Cargo Pod

Flexible Multiple Roto System

Curb (i.e. Empty) weight 700 lb. ~320 kg
Payloads up to 500 pounds (227 kilograms)
8 six-feet diameter propellers, mounted on 4 struts.
Separate rotors can be tilted after takeoff for hor. flt.
15 feet long (4.57m), 18 feet wide (5.49m) and 4 feet tall (1.22 m
(Drones are ~ 50 lbs. (23 kg))

E-VLT Stability and Control Mechanics



Did you recognize that each rotor has a different pitch angle, with different lift and thrust?

Guardian Agriculture's SC1 Aircraft is the First e-VTOL Authorized to Operate with Agriculture Exemptions
replace existing CREWED Aircraft Agricultural Operations.

Multi-Rotor/Copter
with
“Drone-like Operations”.

Empty Weight = 236 lbs (107 kg)
Full load T. O. Weight = 494 lbs (224 kg)
4 six-feet diameter propellers – 12 ft x 12 ft overall dim.
Powered by a 9.1 kWh battery

VOLO Multirotor Drone: VoloDrone
Light-lift Urban Logistics

**Agriculture,
Construction
Logistics,
Public Services,
Island Hopping,
and
Ship to Shore
Operations**

Max. Payload = 200 kg (441 lbs)
Maximum T. O. Weight =600 kg (1323 lbs)
Overall Drone diameter 9.15 mt; Height 2.15 mt
Maximum range 40 Km (25 m)
Powered by 18 independent rotors-motors

Beta Lift + Cruse e-VTOL

ECTOL Cruse Mode

Alia-250 is targeting a maximum range of 250 nautical miles (463 kilometers) to carry 1,400 pounds (635 kilograms) payload.

VTOL Lift, Hover, Loiter and Cruse Modes

CX300
Airport-to-airport
all-electric airplane

ALIA-250
Electric vertical takeoff
& landing aircraft

Beta intends to certify an electric fixed-wing CX300 e-CTOL by 2024 for as a Part 23 utility aircraft in piloted electrically powered flight operations. Passenger aviation is the ALIA-250 focus taking the stepwise approach through military, medical, and cargo on our path to a passenger aircraft and then adding a certified e-VTOL vehicle option.

Joby Tilt-rotor

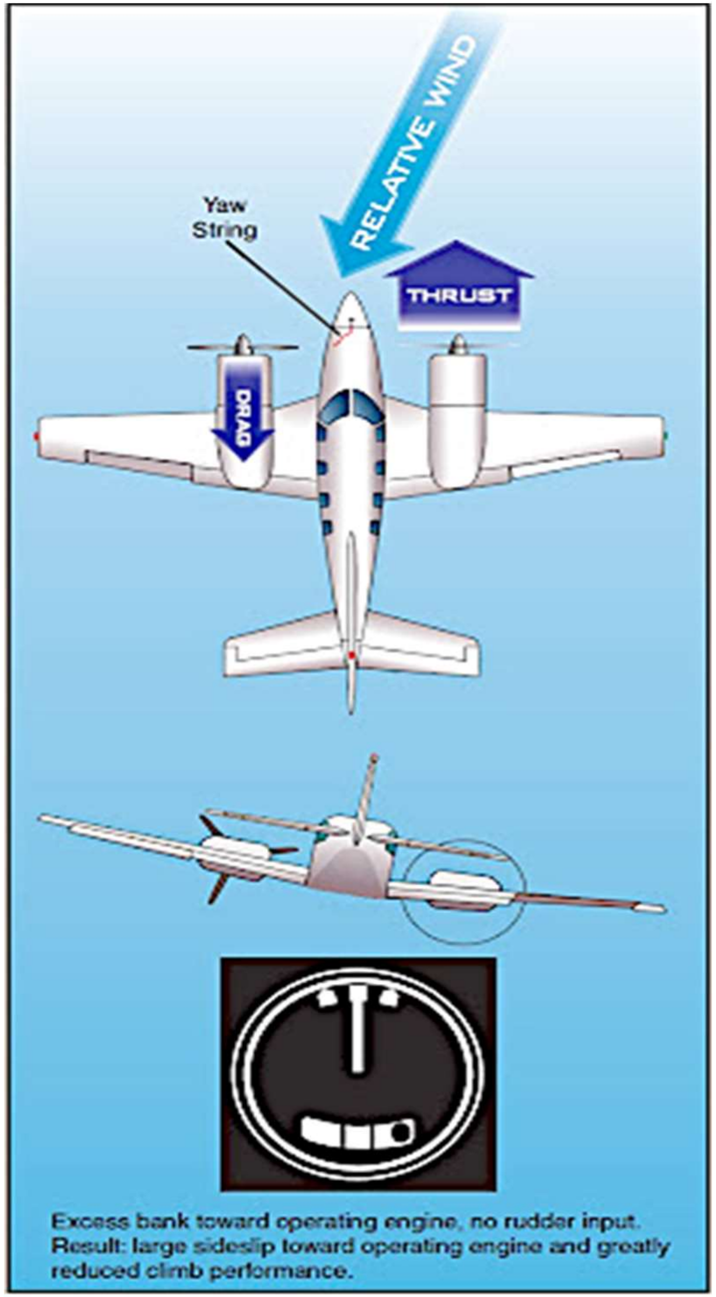
VTOL Lift, Hover and Loiter Modes

VTOL Cruse Mode

Addresses;
- Blade-lift dissimilarities - high-speed limitation

One Engine/Rotor Inoperative (OEI)/(ORI)
System (vehicle) sensitivity.

Joby's Tilt-rotor is in a USAF Operational Test and Evaluation to determine operationally effectiveness and suitable for their decision to buy and operate the airplane.
Maybe a future technology option to the CV-22 tilt-rotor architecture.



What is OEI

One engine inoperative (OEI) is a condition where one of the engines on a multi-engine aircraft fails and as a result, a thrust imbalance exists between the operative and inoperative sides of the aircraft. This thrust imbalance (asymmetrical thrust) causes several negative effects in addition to the loss of one engine's thrust.

A yawing moment develops, which applies a rotational force to the aircraft tending to turn it toward the wing that carries the engine that failed.

The yaw and roll forces must be counteracted by a combination of rudder and aileron.

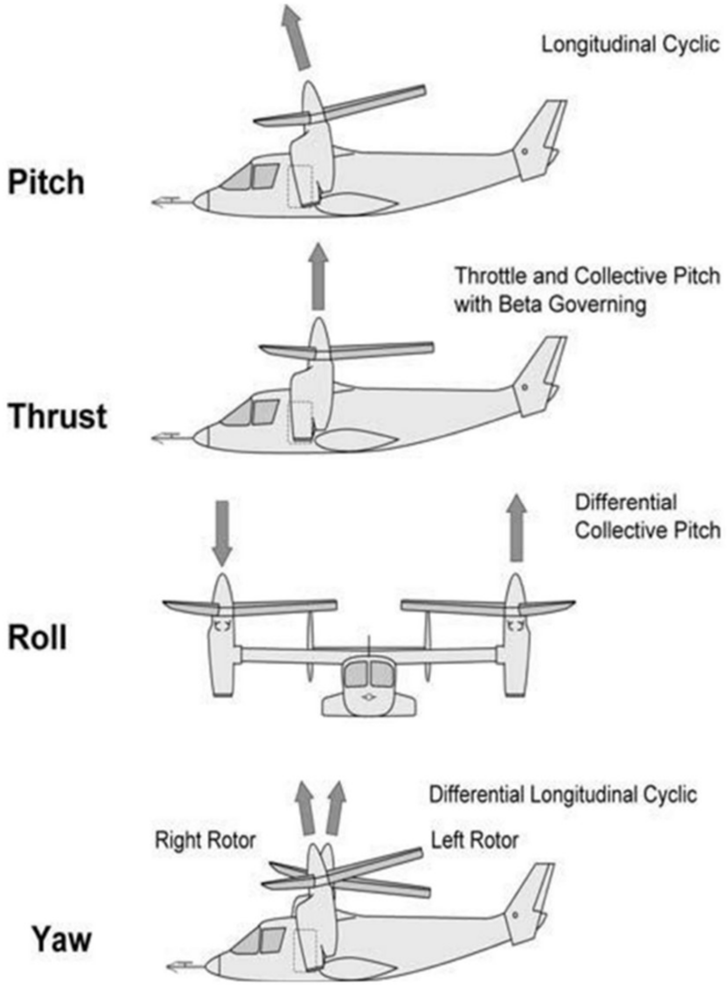
A safe OEI maneuvering altitude, typically at least 400 feet above ground level (AGL) for CTOL up to 1,000 for VTOL at "High" operating altitudes.

CONTINUED SAFE FLIGHT

What happens when a rotor or battery-pack fails, ORI?

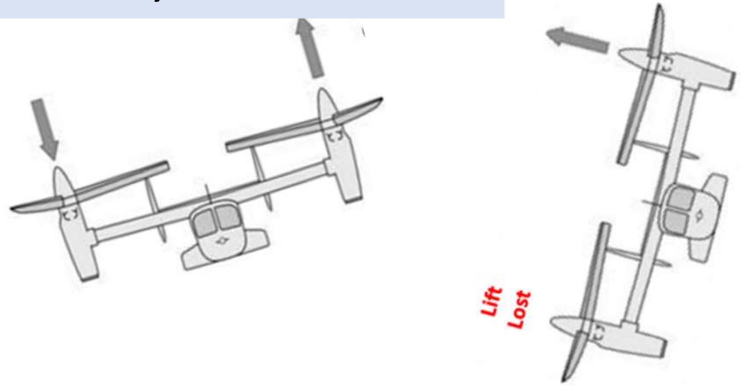
Rotor System(s) Lift Dissymmetry

Tilt Rotor Architecture ***ORI*** *Sensitivity*



- **Rotor System dissymmetry different than Blade Lift dissymmetry.**

Stable Lift, Hover and Roll



ORI Unstable Control

Military Osprey Tiltrotor Aircraft
Crash In Japan, 28 Nov 2023

- US Marines & Air Force special operations units use the **CV-22**:
  - Faster than conventional helicopters to approach enemies from unexpected angles (**Agile & Maneuverable**)
  - In and out of areas without established runways, where fixed-wing planes may not be able to land with troops and supplies.
  - Combat Search And Rescue missions, **CSAR, --** find and rush wounded troops to emergency care.
  - **Payload:** 4 crew plus 24 personnel (seated), 32 personnel (floor loaded) or 10,000 pounds of cargo.

Marine Corps Air Station Iwakuni Japan

Combinations of pilot error and mechanical failures have contributed to periodic Osprey crashes.

ORI Event

8 Airman Died.

Cause undetermined? Hard Clutch Engagement *Incident?*

Rotor System(s) Lift Dissymmetry?

U.S. Military Planes Grounded Pending Investigation

CONOPS Dependent Guidance:
Managing Operational Safety, Range and Reserves
Battery Powered-Electric Aircraft

- Helicopters and fixed wing aircraft use **FADECs**
  - Electronic Engine Controller (EEC) or Engine Control Unit (ECU)
  - **Battery Management System, BMS**
  - Uses performance model for a fuel propulsion management system

Flight Management Systems (FMS) uses FADAC data for

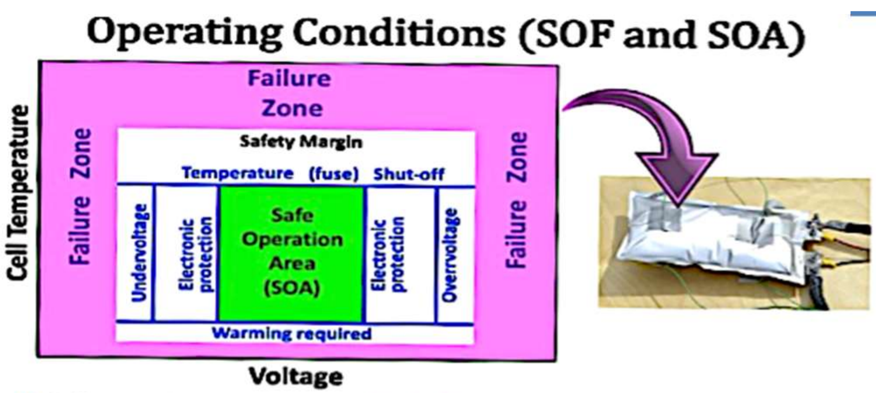
Different Phases of the Flight Energy-management Decisions

- **Extended diversion time operations** (**EDTO**) operation by an airplane with two or more turbine engines or rotors, diversion time to an in-route alternative.
  - Safe flight with one engine - rotor inoperative **(OEI)/(ORI)**
  - Forced Landing sites (location and available power/fuel/time)
- **Reserves fixed or tailored by operational needs and vehicle architecture**
- **Similar capabilities/guidance needed**
  - High voltage energy storage and fuel-cell propulsion systems

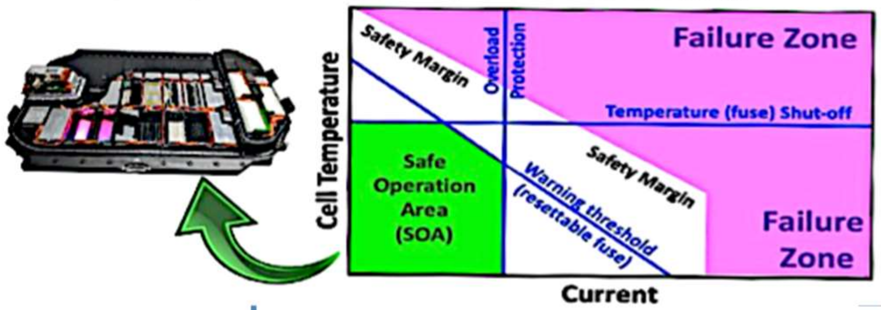
(Analogy with Legacy Fuel Concepts)

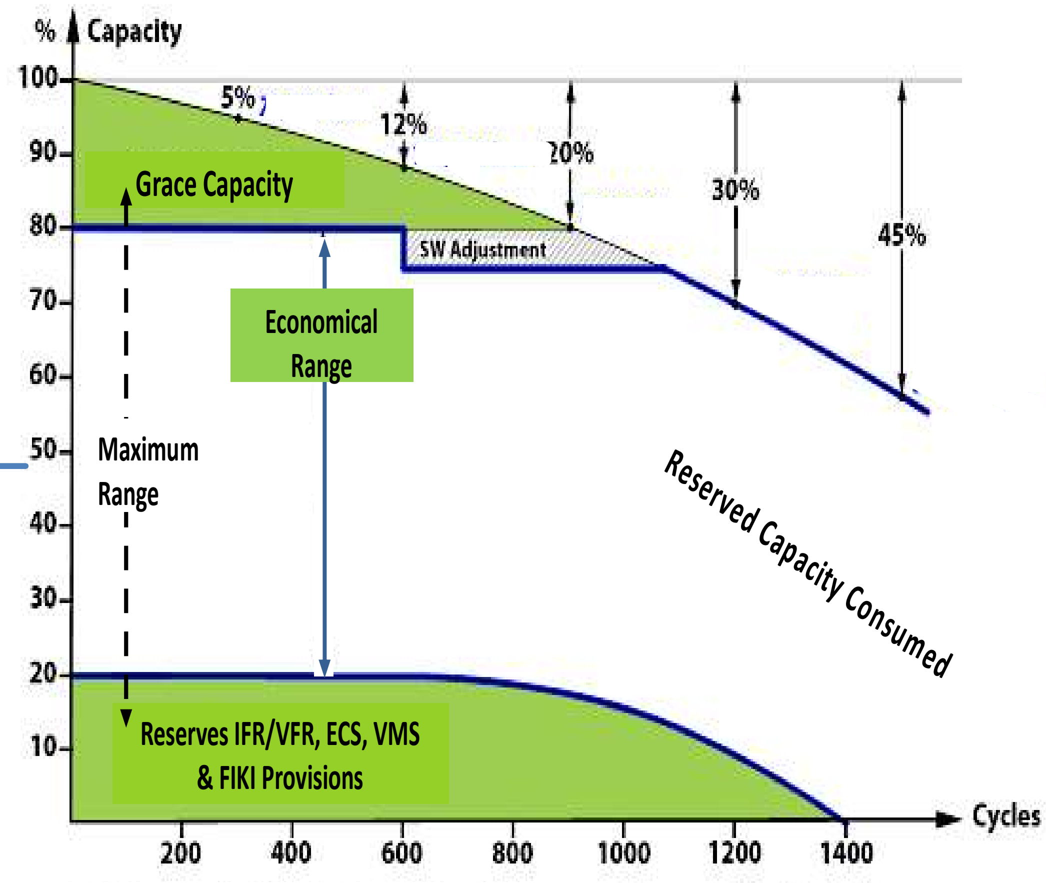
  - Near-Term, Special Conditions
  - Longer-term, Powered Lift guidance

Technical and Regulatory Inputs
Management Of On-board Battery Energy Systems.



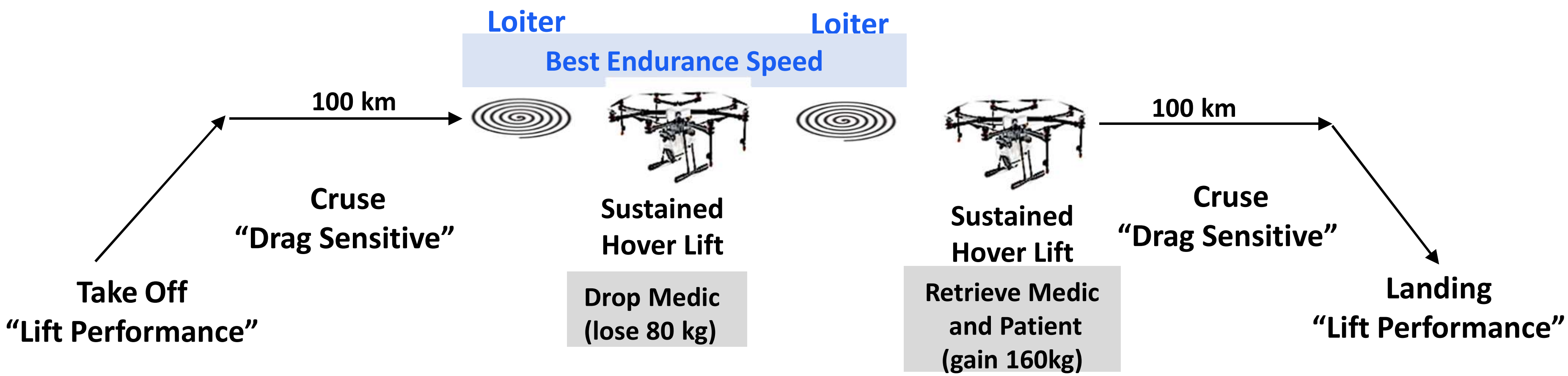
- Cell manufacturers provide limitations such as upper/lower voltage, charge/discharge current, operating temperature range…
- Outside these values, Battery deteriorates (Lithium plating, Capacity loss…) or becomes at serious risk (short circuit, runaway…)
- BMS monitors SOF (State Of Function) and forecasts SOC and SOH
- SOA (Safe Operation Area) also depends on Battery ageing





Battery Management System (BMS) -- Safety, Function
Flight Operations (incl. No-Go Conditions) and Durability (Life)

Contingency Fuel Planning for a Search and Rescue, SAR, Mission



- Type Certification, *Vehicle Capability*
- Operational Certification, *Safe/Efficient Operations*
  - Typically, Part 135
  - Reserve power for unexpected weather, ORI and ATM/ATC Contingencies
    - Fuel or power weight dispatch requirements
    - Flight planning weight trades effect payload/ range performance

Power (fuel) & Flight planning ESSENTIAL for

Converting Vehicle Capability Into Operational Utility

Power (Fuel) Planning for Notional Search And Rescue SAR Mission

Momentum Simulation					
Mission Phases	Altitude	Speed	Cargo Payload Changes (kg/lbs)	Planed Distance	Planed Leg Fuel Consumed Kg
Take-off	Sea Level	Hover			26.7
Flight out	Sea Level	70 m/sec		140 km/82 m	99.3
Loiter	Sea Level	50 m/sec			17.6
Sustained Hover	Sea Level	Hover			52.2
Loiter	Sea Level	50 m/sec	Drop Medic lose 80 kg., 176 lbs.		35.1
Sustained Hover	Sea Level	Hover	Retrive Medic and Patient add 160 kg., 353 lbs		50.6
FlightBack	Sea Level	70 m/sec		140 km/82 m	98.6
Land	Sea Level	Hover			25.2
Mission Planning (out & return)				280 km. 164 miles	405.3
					Planed Fuel

- Momentum methodology

  Westland Lynx data

  Typical SAR mission

  - 4 Hover demands
  - 2 Loiter
  - 2 cruse segments
  - 1 reduction in payload
  - 1 increased payload
- Similar elements to cargo logistic power demand elements
  - Cargo delivery (reduced payload)
  - Cargo transportation with changing payloads.

Contingency Fuel Planning for a Search And Rescue, SAR, Mission

Momentum Simulation						Contingencies					
Mission Phases	Altitude	Speed	Cargo Payload Changes (kg/lbs)	Planed Distance	Planed Leg Fuel Consumed Kg	Added Fuel Weight Fractional Reserve Factors	Added Individual Fractional Fuel Reserves	Total Fuel Kg	Planed Times (m)	Contingency Reserve Times (m)	Total Time
Take-off	Sea Level	Hover			26.7	0	0.00	26.70	5	0.00	5.00
Flight out	Sea Level	70 m/sec		140 km/82 m	99.3	0	0.00	99.30	23.8	0.00	23.80
Loiter	Sea Level	50 m/sec			17.6	3%	0.53	18.13	5	0.15	5.15
Sustained Hover	Sea Level	Hover	Drop Medic lose 80 kg., 176 lbs.		52.2	5%	2.61	54.81	10	0.50	10.50
Loiter	Sea Level	50 m/sec			35.1	3%	1.05	36.15	10	0.30	10.30
Sustained Hover	Sea Level	Hover	Retrive Medic and Patient add 160 kg., 353 lbs		50.6	5%	2.53	53.13	10	0.50	10.50
FlightBack	Sea Level	70 m/sec		140 km/82 m	98.6	0	0.00	98.60	23.8	0.00	23.80
Land	Sea Level	Hover			25.2	0	0.00	25.20	3.8	0.00	3.80
Mission Planning (out & return)				280 km. 164 miles	405.3	-	6.72	412.02	91.4	1.45	92.85
					Planed Fuel	Contingency Fuel		TOTAL	Times (Minutes)		
					Final Departure Requirements	130%		536			121
								KGrams			Minutes

Operating Environment example

SAR Lift, Loiter & Hover

Lift is Lost at Hot and High Conditions (6000 ft, -40C -- +40C)

19 km/h – 28 Nov 2023

[Boulder Reservoir, United States]

5,430 feet or **1,655** meters above Sea Level.

07:46:44 am, GMT-6 – wind 19 km/hr., gusting17 km/hr

	SAT, DEC 2								SUN, DEC 3								MON, DEC 4								TUE, DEC 5					
Time	00	03	06	09	12	15	18	21	00	03	06	09	12	15	18	21	00	03	06	09	12	15	18	21	00	03	06	09	12	15
Wind direction	↗	↗	↑	↑	→	→	→	→	→	↘	→	→	↘	↘	↘	→	↗	→	↗	↗	→	↘	→	↗	→	→	→	→	↘	→
Wind speed (km/h)	7.9	17	6.1	7.9	29	37	23	17	15	13	23	31	37	34	14	10	8.6	10	4.3	7.9	14	18	7.9	14	13	15	16	15	6.8	3.6
Wind gusts (km/h)	7.9	26	10	14	51	57	41	27	18	26	40	48	54	63	44	18	16	28	13	16	47	48	14	19	12	14	15	15	12	9.7
Temperature (°C)	-5.2	-3.9	-5.5	-3.0	4.9	5.7	1.2	-0.1	-1.3	-1.4	-4.0	-3.1	0.8	1.3	-0.9	-1.8	-1.2	0.0	-0.1	2.2	9.5	11	6.1	4.2	2.9	1.7	1.1	2.1	11	13
Cloud coverage																														

37 km/h - 28 Nov 2023

Lo Stagnone Island, Italy (Sicily) **Sea Level.**

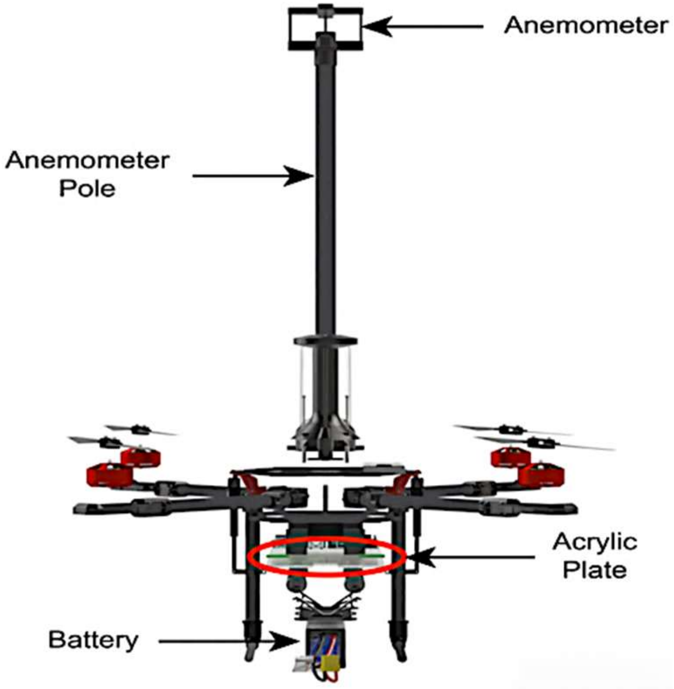
04:09:58 pm, GMT+1 – wind 37 km/hr., gusting 46 km/hr

	THU, NOV 30								FRI, DEC 1								SAT, DEC 2								SUN, DEC 3						
Time	01	04	07	10	13	16	19	22	01	04	07	10	13	16	19	22	01	04	07	10	13	16	19	22	01	04	07	10	13	16	1
Wind direction	↑	↖	↖	↖	↖	↖	↖	↖	↖	↖	↖	↑	↑	↑	↑	↑	↑	↑	↖	→	↘	↘	↘	↘	↘	↘	↘	↘	↘	↘	↘
Wind speed (km/h)	9.7	16	23	34	39	33	32	36	39	45	48	48	46	38	39	40	35	21	3.2	16	33	29	26	28	32	32	28	34	36	30	2
Wind gusts (km/h)	13	19	30	48	49	44	47	53	57	64	67	66	66	55	54	55	50	33	11	29	41	33	29	31	39	36	31	33	37	33	2
Temperature (°C)	16	15	15	17	19	19	18	18	18	18	19	20	20	19	18	18	18	17	17	18	17	17	16	16	15	15	14	15	15	14	1
Cloud coverage																															

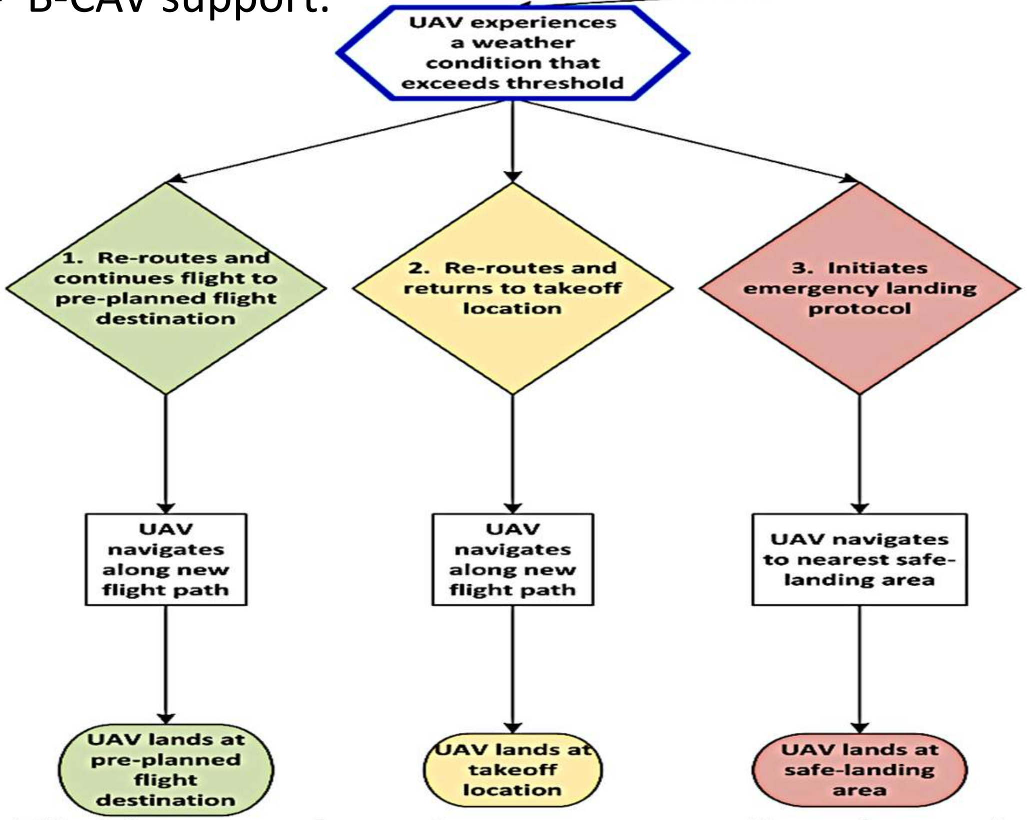
University of Colorado Boulder Team: Flight Management System for Unmanned Aerial Vehicles (Drones) and Contingency Reserves..

Student team design, identifying weather conditions and autonomously changes original intended flight plans of unmanned aerial vehicles as a result.

-- B-CAV support.



An exploded view of the UAV and FMS assembly



Flight scenario outcomes once the drone is in flight and experiences a weather condition that exceeds a threshold

Hot, Heavy and High Operating Environment

SAR Lift, Loiter & Hover

Lift is Lost at Hot and High Conditions (6000 ft, at -40C -- +40C)

ISO SL-Std. Day **is 15° C or 59° F**

A reference rotor airfoil (SC1095) generating 21,000 lbs. sea level thrust,

- At operation in hot conditions hot and high conditions (6000 ft, 1,829 m , 46 C, 115°F),

  Available Trust is About **18,400** Lbs., **- 2,590lb** Loss In Lift.

- Incorporating the SMA **Camber-morphing Skin** extends from the blade root along the inboard blade span can improve lift; https://doi.org/10.1177/1045389X20953613

Reference Rotor Airfoil	% Adaptive Span Camber	Lift, lbs.	Lift Reduction, or Improvement	% Change
SL, 46 °C	**-**	**21,000 lbs.**	**-**	**-**
1,829 m , 46 °C, (115°F),	**0**	**18,410 lbs.**	**-2,590 lbs.**	**-12.35**
	25%		**+290 lbs.**	**11%**
	50%		**+1,137 lbs.**	**40%**
	75%		**2,185 lbs.**	**82%**

Incorporating the SMA camber-morphing skin, along the inboard span, recovered lost lift, Hover & Loiter Performance with a modest power penalty.

Expanding Performance Envelopes

Prescriptive Power (Fuel) Management
Payload-range Effects.
to
Performance Based Contingency Power Management

- Power (Battery) management system integrated into FEDAC supported by data storage will provide a statical correlation between planed versus actual flight planning.

Hot, High and Heavy Thrust/Lift Retention

- Adaptive Rotor Blade Compensating for “Aid-density” Effects

VTL Air Cargo Logistics Opportunities/Challenges

- Conventional drones, helicopter operations and/or other transport options:
  - **Emergency transport** of goods: Transporting required goods when disaster event occurs.
  - **Inter-facilities:** Transporting goods or products between facilities owned by a company/organization.
  - **Cargo delivery** (sea and mountainous areas):

Transporting Cargo Along Routes over the Sea and within Mountain Areas
(Incl. Remote Medical Care and SAR).

  - **Cargo Delivery** for urban areas (UAM) and **Transporting** cargo in Regional Areas, (RAM) regional air mobility.

Concept of Operations (CONOPS) for UAM and RAM are different, FedEx example.

- Various cargo applications expected to deliver products *before passenger transport is permitted*,
  - Cargo transport may bring in more revenue than passenger-derived revenue

Guardian will earn revenue, delivering SC1 in 2024

  - Cargo transport related to humanitarian relief and emergency response will build confidence in, and enthusiasm for**, E-VTOL**.
  - Advanced Flight Simulation Fuel Planning
  - Power based FADEC
- **Italy's** Cargo Transport

Ships, and Trucks, and High-speed Trains - **Utility Aircraft Too?**

Rural-Regional Air-Cargo Options?

Cargo Logistics Options;

Which CAPABILITY satisfies specific CONOPS needs?

Trucks and Trains, and (Also ?) some Airplanes

High Speed Rail ?

e-VTOL Urban Air Cargo	e-STOL Regional Air Cargo

Technology Competition ⟷ Capability/Utility

Abbiamo finito

Forza Napoli

Buon Anno Nuovo